RESEARCH ARTICLE

Analysis of Overcut on 316l Stainless Steel during Micro EDM Drilling

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ABSTRACT: This paper describes the micro EDM process performance parameter study on Overcut while drilling micro hole on 316L stainless steel. The important parameters such as voltage, capacitance and Sparkgap are considered for micro hole drilling. Totally 27 experiments were conducted to study the selected parameters effects. The results clearly show that the voltage plays the key role and capacitance dominates than sparkgap.

KEYWORDS: Micro EDM, Overcut and Micro Hole

INTRODUCTION:

The μEDM is one of the important emerging technologies for manufacturing miniaturized components and systems. To explore its potential, research attempts are being made all around the world amongst the scientific community. Hideki et al [1] developed μEDM, a machining center that utilizes rapidly the sharpened electrodes to implement precession machining. They concluded that, less than 20 μm diameter electrodes were formed through ECM by a single discharge. Eberhard and Sumet [2] introduced the orbital motion to the electrode to increase the efficiency of micro hole drilling. They concluded that the orbital motion of the electrode increased the hole diameter proportionally to the orbital radius. A larger hole diameter increases the flushing and reduces the electrode wear and creates better surface finish. The μEDM process is basically similar to the EDM process. The main difference between EDM and μEDM is based on the size of the tool used, power supply used in μEDM and the X, Y and Z axis movement. (Masuzawa et al [3] clearly described the μEDM principles, types of EDM processes, dielectric fluids, electrodes, tool feed control using logic fuzzy, piezo-actuated tool feed control, process parameters for MRR and TWR. They concluded that the study helps the researchers to develop a μEDM machine. Hewidy et al [4] studied surface roughness at different duty factors and flushing pressures. From experimental results it is established that the surface roughness slightly increases with the increase of peak current value. Hung et al [5] used ultrasonic vibration with μEDM combined to drill micro-holes by a helical micro-tool electrode to achieve good surface quality and less taper of the holes wall. They concluded that the helical electrode for μEDM combined with ultrasonic vibration produces the precise shape of the micro holes and smooth surface finish. Kim et al [6] investigated reverse EDM process to fabricate multiple electrodes with various shapes to fabricate multiple electrodes on WC rods, they first machined micro holes on copper plates. Then using reverse EDM process they fabricated the multiple electrodes on the WC rod. They machined micro holes on stainless steel workpiece using the fabricated electrodes by the reverse EDM. They found the optimum voltage and capacitance for that process. Gwo et al [7] studied the burr formation in micro machining using micro tools fabricated by μEDM. A tungsten-carbide micro tool with diameter of 31 um has been fabricated by the combination of micro-milling and grinding processes, Micro-slot and micro thin-walled structure was fabricated on Al 6061-T6 materials. A brief investigation was made on the burr formation in micromachining and classified into primary burr, needle-like burr, feathery burr and minor burr. They reported that, the burr formation is avoided by keeping the minimum axial engagement and minimum of feed. Qing et al [8] used the ANN and Genetic algorithm (GA) to establish the parameter optimization model. An ANN model which adapts Levenberg-Marquardt algorithm has been set up to represent the relationship between MRR and input parameters, and GA is used to optimize parameters. It was concluded that the model is very effective, and MRR is improved using optimized machining parameters. Tan et al [9] investigated the effect of nanopowders additives during the μEDM on AISI 420 stainless steel. They reported that SiC and Al_2O_3 nanopowders reduce the surface roughness during the μEDM operations. Murali et al [10] introduced an ultrasonic vibration to the work-piece to maximize the MRR and minimize the tool wear. From the investigation, ultrasonic vibration and peak power with capacitance are significant for improving MRR. Takashi et al [11] introduced vibration assisted machining to μEDM using PZT to flush out the debris between the electrodes. Using vibration assisted machining; a small square shaft was fabricated. They concluded that the vibration assisted machining improves the machining stability and reduces machining time.

Pradhan et al [12] optimized μEDM process parameters on machining of Ti-6Al-4V super alloy. The most influence of machining parameters such as peak current, pulse-on-time, dielectric flushing pressure and duty ratio was considered. The performance criteria such as MRR, TWR, over cut and taper were examined. A performance study was made by Jahan et al [13] in Tungsten carbide (WC) to achieve good quality micro holes using transistor and RC type generators. It was concluded that the RC pulse generator produced better quality micro holes in WC, with rim free of burr-like recast layer, good dimensional accuracy and fine circularity. Kung et al [14] introduced powder mixed EDM when machining of cobalt-bonded tungsten carbide. The MRR and EWR were chosen as outputs. The response surface methodology (RSM) was used to plan and analyze the experiments. They concluded that the aluminium powder mixed with dielectric fluid increases the MRR and reduces

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the EWR. Pradhan et al [15] optimized the PMEDM parameters on Ti6A1-4U alloy. MRR, tool wear rate, over cut and taper are the responses chosen. The optimum results were obtained through ANOVA and S/N ratio graph. They concluded that the peak current and pulse on-time were the most affected parameters. Aravind et al [16] developed an Artificial Neural Network to predict the MRR. Voltage, capacitance, feed, electrode speed are taken as input parameters. The experiments have been conducted based on the Design of Experiments. The developed ANN model is used for training and testing the experimental data. For Training the model 75% of the data is used and the remaining data for testing. They concluded that the developed model is well suitable to predict the MRR in μEDM process. Somashekar et al [17] developed a feed forward neural network with back propagation model to predict the MRR and overcut in micro wire electric discharge machining on aluminum plate. Voltage, capacitance and feed rate were chosen as input parameters. They concluded that the predicted ANN results well agreed with the experimental results.

EXPERIMENTAL STUDY:

Experiments were conducted to study the effect of process parameters such as Voltage, Capacitance and Sparkgap on MRR and Overcut. Three levels in all the three parameters were chosen for conducting the experiments. A full factorial design (Montgomery 2005) was used to conduct the experiments. The plan of experiment was made of 27 tests and repeated once for consistency. Totally 54 tests were conducted to study the objectives. Table 1 shows the machining parameters and their levels used for the experiments. Tungsten wire of diameter 380 μm is used as a tool electrode and it made is cathode. A 316L stainless steel of thickness 200 μm is used as the workpiece material, since it has many applications such as for manufacturing micro punches and dies and it is made as the anode. The composition of the work material is shown in Table 2. The workpiece was rigidly held in a position by using fixture. The de-ionized water was used as dielectric medium in the experiments. A RC type of power supply of 300 V and 5A with the capability for varying voltage, capacitance and resistance to the required values within the specified range is used.

Table 1 Process parameters and their levels

Parameters	Voltage (V)	Capacitance (pF)	Sparkgap (μm)
Level 1	80	200	28
Level 2	100	300	32
Level 3	120	500	36

Table 2 Composition of 316L stainless steels

C	Mn	Si	P	S	Cr	Mo	Ni	N
0	2	0.8	0	0	18	3	14	0.1

3. STUDY ON INFLUENCE OF PROCESS PARAMETER ON OVERCUT:

The overcut of the micro hole has been considered as one of the machining accuracy criteria. It is the difference between the diameter of the machined hole and the diameter of the tool electrode. The Table 3 shows the experimental values and overcut.

Table 3: Experimental values and results for overcut

Sl. No.	Voltage (V)	Capacitance (PF)	Sparkgap (μm)	Average Overcut (μm)
1	80	200	28	169.186
2	100	200	28	216.552
3	120	200	28	259.436
4	80	300	28	199.306
5	100	300	28	236.631
6	120	300	28	280.156
7	80	500	28	226.144
8	100	500	28	267.351
9	120	500	28	307.836
10	80	200	32	149.114
11	100	200	32	179.598
12	120	200	32	240.245
13	80	300	32	174.474
14	100	300	32	215.678
15	120	300	32	252.842
16	80	500	32	199.833
17	100	500	32	234.077
18	120	500	32	282.242
19	80	200	36	125.75
20	100	200	36	172.556
21	120	200	36	231.36
22	80	300	36	157.19
23	100	300	36	184.635
24	120	300	36	214.421
25	80	500	36	174.87
26	100	500	36	206.714
27	120	500	36	251.918

3.1 Effect of Voltage on Overcut

To study the effect of voltage on overcut, the sparkgap and capacitance were kept constant. From Figure 1, it is observed that, with increase in voltage, the overcut increases. This is because, the energy discharge from the tool electrode increases with increase in voltage. Due to this, higher temperatures are generated between the electrodes. This results in higher overcut

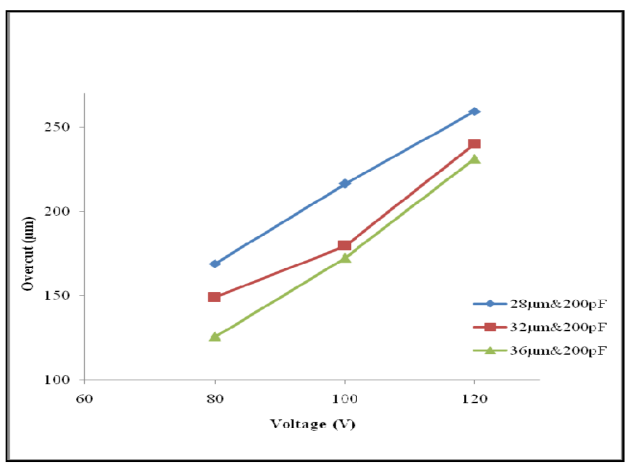

Figure 1. Effect of voltage at 200 pF capacitance

3.2 Effect of Capacitance on Overcut

To study the effect of capacitance on overcut, the other two input parameters such as voltage and sparkgap are kept constant. From Figure 2 it is observed that, with increase of capacitance the overcut increases. This is because; the energy discharged from the capacitor increases. Therefore higher energy results in higher overcut.

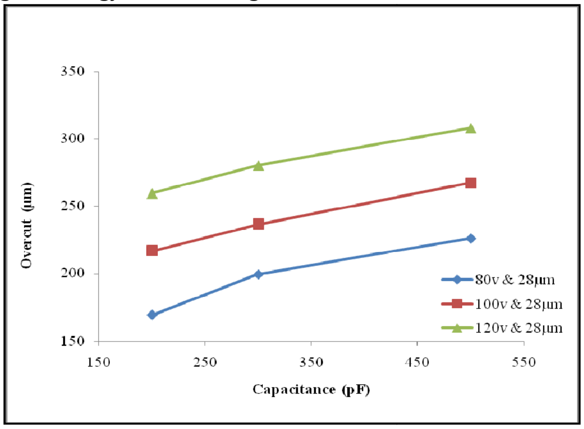

Figure 2. Effect of capacitance at 28µm

From the Figure 2 it is also observed that at capacitance 300pF, voltage 120V and sparkgap 36µm the overcut is lesser than the capacitance 200pF, voltage 120V and sparkgap 36µm. This is because, sufficient machining time is not given during machining.

3.3 Effect of Sparkgap on Overcut

To study the influence of the sparkgap on overcut, capacitance and voltage were kept constant. The effect of sparkgap on overcut is shown in Figure 3. With the increase in sparkgap, the overcut decreases. This is because, when the distance between electrodes increases, the thermal energy discharged from the electrode towards the work piece is less, resulting in lower overcut. Higher capacitance, results in higher discharge energies and so overcut increases. It is also observed that, overcut is higher for higher capacitance and it decreases with decrease in capacitance.

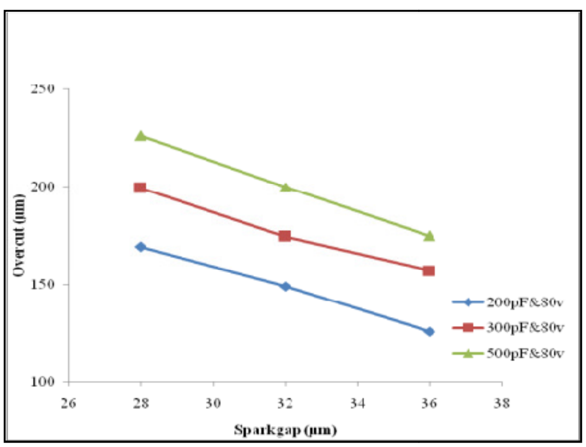

Figure 3. Effect of sparkgap at 80Voltage

4. ANALYSIS OF OVERCUT

To find the optimum parameters for lesser overcut the Taguchi Equation is used for calculating S/N ratio. The Table 4 shows the experimental value and S/N ratio for lesser overcut.

According to the Table 4, the optimum combination of process parameter for lesser overcut is voltage of -45.45, capacitance of -45.53 and sparkgap of -45.45. Larger values of the S/N ratio in the graph or in the S/N ratio table indicate that the smaller is the variance of the performance characteristics around the desired value.

Table 4 Mean S/N ratio for lesser overcut

Sl.No.	Symbol	Factor	Level 1	Level 2	Level 3	Maximum
1	A	Voltage	-45.45	-46.46	-47.49	-45.45
2	B	Capacitance	-45.53	-46.43	-47.44	-45.53
3	C	Sparkgap	-47.49	-46.46	-45.45	-45.45

The mean S/N ratio for overcut is displayed graphically in Figure 4 The overcut for each factors level indicates the relative effects of the various factors, A: Voltage, B: Capacitance and C: Sparkgap on the machining performance and characteristics such as overcut. From the S/N response graph Figure 4 for minimum overcut, the optimal parametric combination is A1, B1, and C3. i.e Voltage at 80V, Capacitance at 200pF and Sparkgap at 32µm.

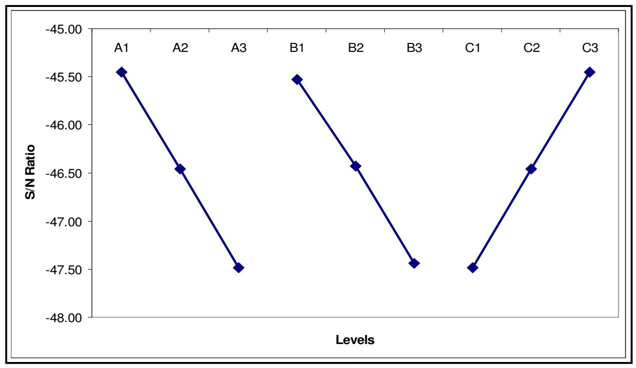

Figure 4. S/N ratio graph for overcut

5. CONCLUSIONS

The research of the present work is summarized. Experiments were conducted to study the individual effects and optimize the µEDM process parameters. From the experimentation the flowing are the conclusions drawn from the present investigations.

The overcut increases with increase in voltage and capacitance. When the sparkgap increases the overcut decreases. Based on the Taguchi technique, Signal to Noise ratio, analysis of variance and F-test values have been calculated. Based on these analyses, the significant process parameters affecting the overcut have been identified. The optimum combination for lesser overcut is at lesser voltage, minimum capacitance and maximum sparkgap. The voltage is highly dominating parameter, sparkgap is the second dominating parameter than the capacitance. The voltage contributes 58.18%, sparkgap contributes 20.41%, and capacitance contributes 18.06% towards overcut.

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